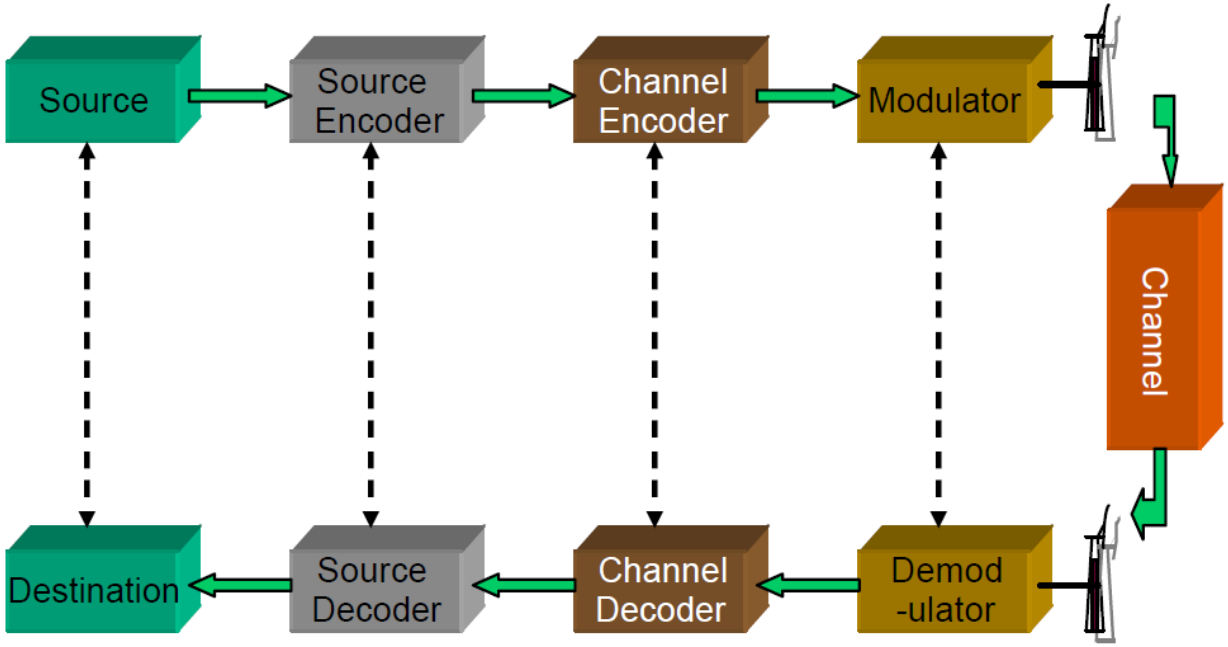
Digital modulation techniques

Modulations systems



Channel capacity

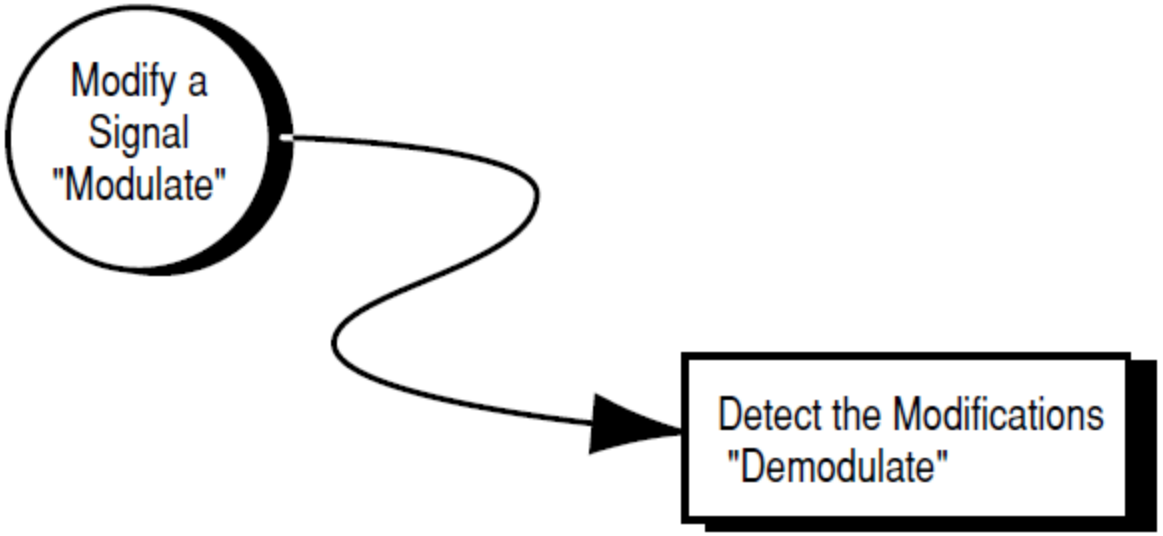
- Channel Capacity (C)
  - the maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions
- Data rate (bps)
  - rate at which data can be communicated , impairments, such as noise, limit data rate that can be achieved
- Bandwidth (B)
  - the bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium (Hertz)
- Noise (N)
  - impairments on the communications path
- Error rate - rate at which errors occur (BER)
  - Error = transmit 1 and receive 0; transmit 0 and receive 1

Reasons for choosing encoding techniques

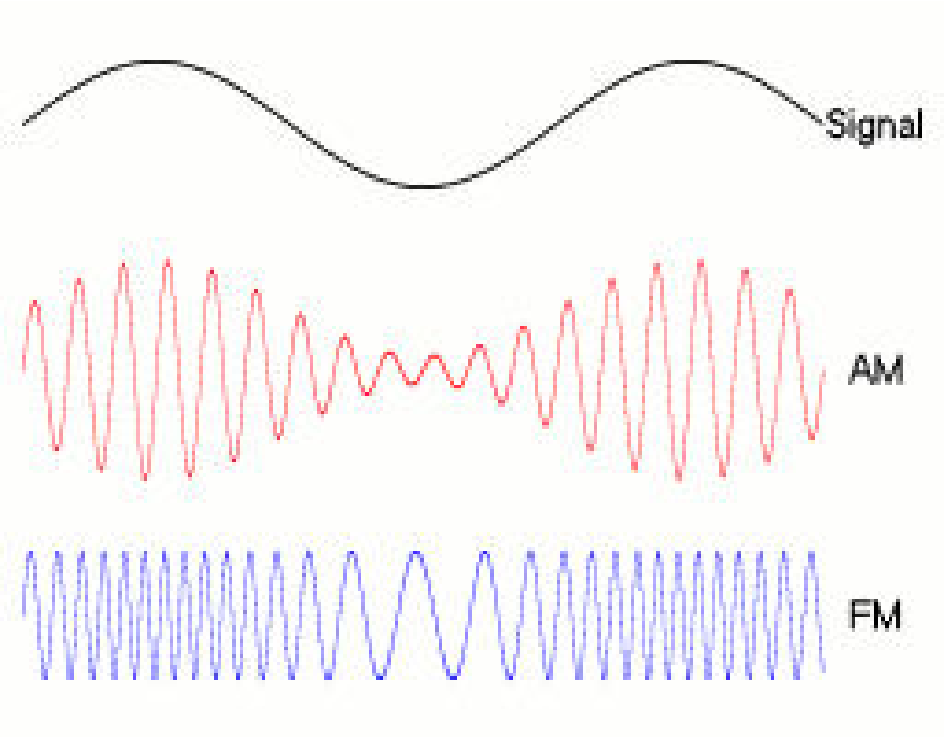
- Digital data, digital signal
  - Equipment less complex and expensive than digital-to-analog modulation equipment
- Analog data, digital signal
  - Permits use of modern digital transmission and switching equipment
- Digital data, analog signal
  - Some transmission media will only propagate analog signals
  - E.g., unguided media (air)
- Analog data, analog signal
  - Analog data in electrical form can be transmitted easily and cheaply
  - E.g., AM Radio

What is modulation ?

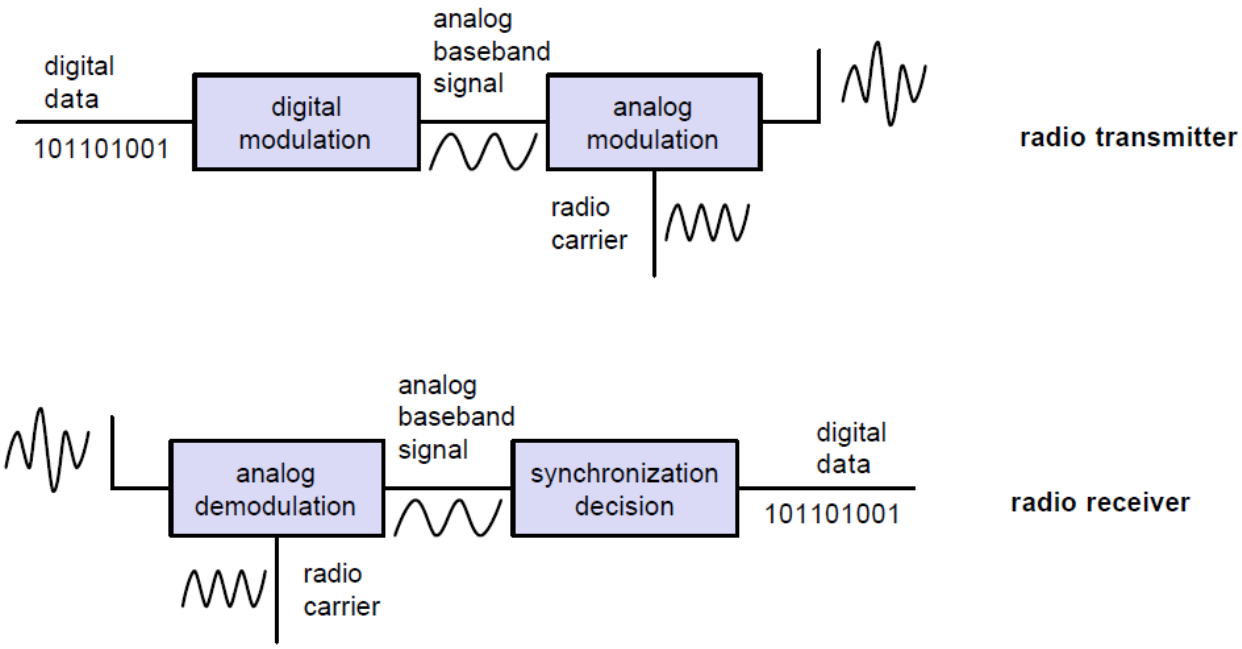
- Modulation = Adding information to a carrier signal
- The sine wave on which the characteristics of the information signal are modulated is called a carrier signal



Analog modulation



Digital modulation and demodulation



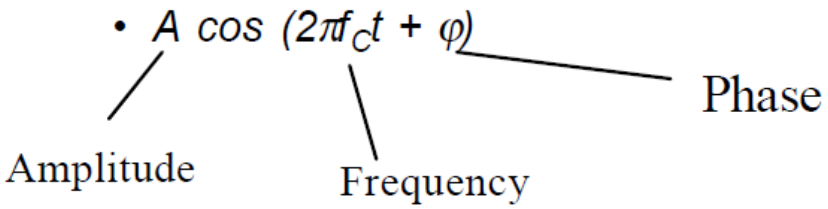
Signal characteristics that can be modified

signal $x(t) = A \cos(2\pi ft + \Phi)$

- A – amplitude
- f – frequency
- Φ – phase (initial angle of the sinusoidal function at its origin

Modulation

- Modulation
  - Converting digital or analog information to a waveform suitable for transmission over a given medium
  - Involves varying some parameter of a carrier wave (sinusoidal waveform) at a given frequency as a function of the message signal
  - General sinusoid



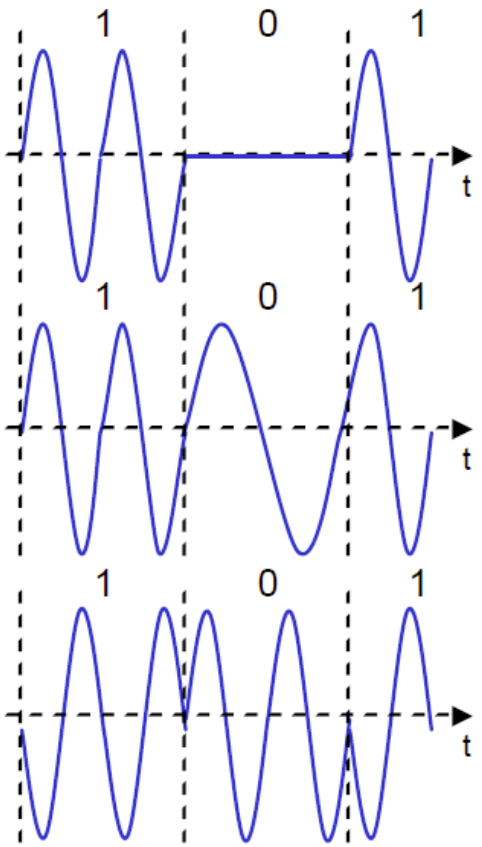
  - If the information is digital changing parameters is called "keying" (e.g. ASK, PSK, FSK)

Modulation (1)

- Motivation
  - Smaller antennas (e.g., λ /4 typical antenna size)
    - λ = wavelength = c/f , where c = speed of light, f= frequency.
    - 3000Hz baseband signal => 15 mile antenna, 900 MHz => 8 cm
  - Frequency Division Multiplexing – provides separation of signals
  - medium characteristics
  - Interference rejection
  - Simplifying circuitry
- Modulation
  - shifts center frequency of baseband signal up to the radio carrier
- Basic schemes
  - Amplitude Modulation (AM) — Amplitude Shift Keying (ASK)
  - Frequency Modulation (FM) — Frequency Shift Keying (FSK)
  - Phase Modulation (PM) — Phase Shift Keying (PSK)

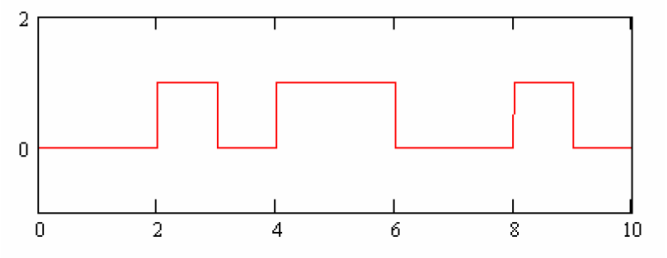
Digital modulation techniques

- Amplitude Shift Keying (ASK):
  - change amplitude with each symbol – frequency constant
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - change frequency with each symbol
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - Change phase with each symbol
  - More complex
  - robust against interference

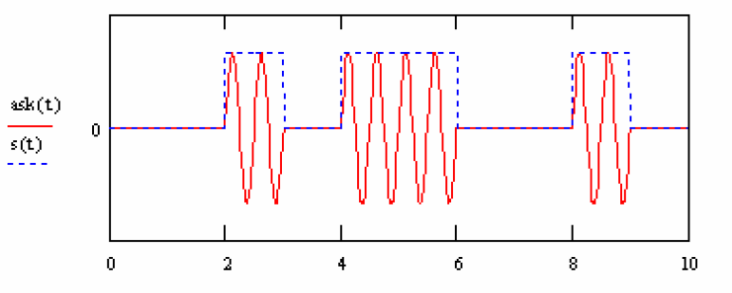


ASK

- ASK On-off keying (Amplitude Shift Keying) – frequency is kept constant, amplitude has 2 levels (for bit 1 and for bit 0)



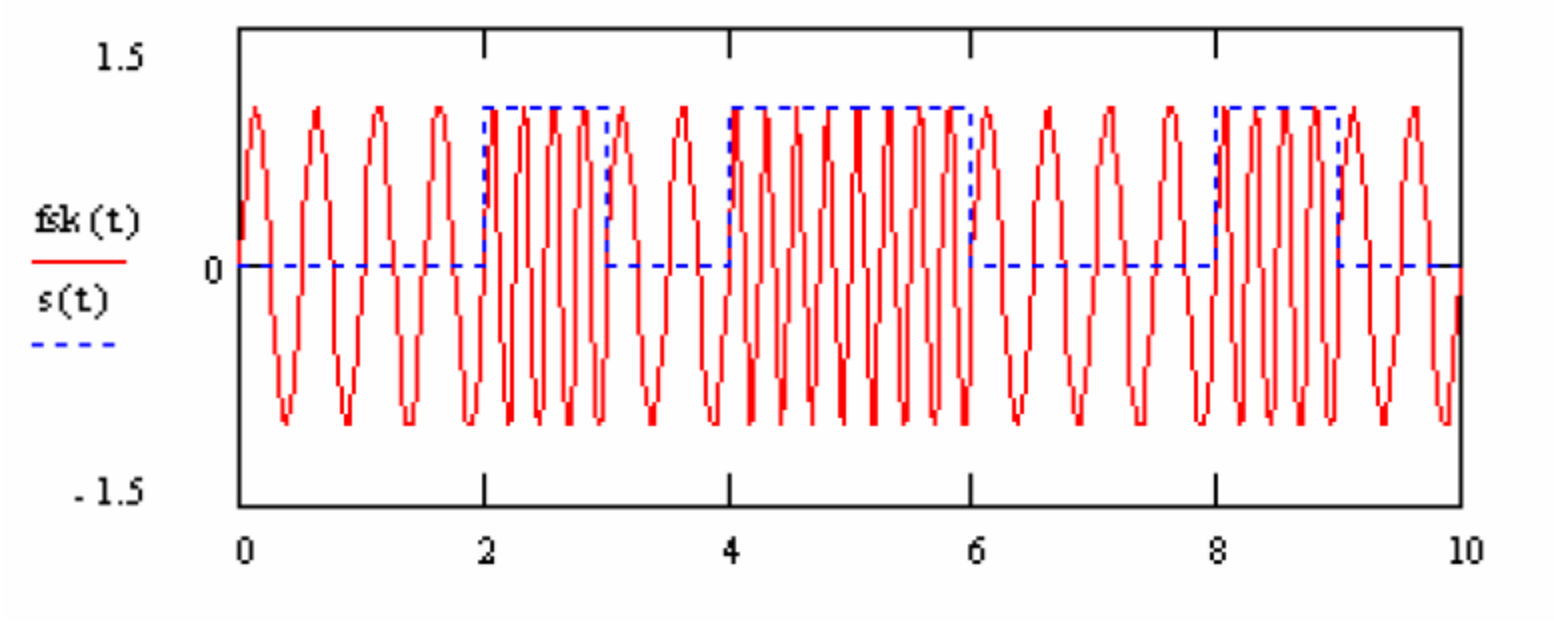
$$ASK(t) = s(t)\sin(2\pi ft)$$



The binary sequence 0010110010

FSK (Frequency shift keyring)

$$FSK(t) = \begin{cases} \sin(2\pi f_1 t) & for\ bit\ 1 \\ \sin(2\pi f_2 t) & for\ bit\ 0 \end{cases}$$



PSK (Phase shift keyring)

$$PSK(t) = \begin{cases} \sin(2\pi f t) & for\ bit\ 1 \\ \sin(2\pi f t + \pi) & for\ bit\ 0 \end{cases}$$